SE7 Implantable and Prosthetic Devices: Life-Changing Circuits

Organizer: Reid Harrison, University of Utah, Salt Lake City, UT
Chair: Ken Wise, University of Michigan, Ann Arbor, MI

Advances in the miniaturization of electronics and an increased understanding of neurophysiology during the twentieth century have led to a rapid growth in neurological technologies – circuits that communicate directly with the human nervous system. Today, analog and mixed-signal integrated circuits form the heart of implantable devices that restore hearing to the profoundly deaf and calm the tremors of Parkinson's disease. Technologies to stimulate paralyzed muscles and restore vision to the blind are becoming a reality as well. Yet circuits that must operate within the body present enormous technical challenges. Power dissipation is extremely limited since excess heat can damage surrounding tissue, and power typically must be delivered wirelessly. The speakers in this special session have backgrounds spanning technology and medicine, and bring a multidisciplinary perspective to this exciting field.

Dr. Denison will provide an overview of pacemaker development and show how this well-established technology is leading to new circuits for "deep brain" stimulation to treat disorders such as Parkinson's or epilepsy. Prof. Loeb will describe small, implantable ASICs for neuromuscular stimulation. Prof. Seligman will discuss cochlear implants – one of the most successful neural interfaces developed in the past few decades – which restore hearing to tens of thousands of deaf persons worldwide. Prof. Liu will describe efforts to restore functional vision to patients who suffer from retinal degeneration. This session will introduce attendees to the challenging field of biomedical microelectronics that promises to improve the quality of life for millions of people in the coming decades.

Panelists Statements

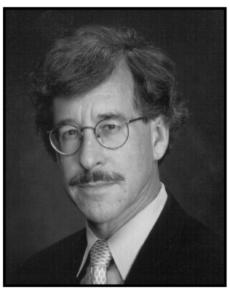
Troubleshooting the Brain: Circuits to Help Neurological Disorders

Tim Denison, Medtronic Neurological Technologies, Columbia Heights, Minnesota

Biological systems are embedded with complex, bio-electrical circuits. Heart attacks, seizures, and other problems result when these biocircuits fail. Engineers can help "repair" damaged biocircuits with silicon alternatives, as shown by the proliferation of pacemakers and defibrillators.

A relatively new area for biocircuit troubleshooting is the field of "deep brain" stimulation to treat disorders such as Parkinson's or epilepsy. These therapies place electrodes within the brain to focus treatment on a key neural circuit. Just as with pacemaker technology, deep brain stimulation is becoming more sophisticated as our understanding of the underlying biological circuits grows.

This talk will provide an overview of the challenges engineers face when developing deep brain stimulation devices. After providing a brief overview of key neural circuits, and setting the context for pacemaker evolution, the discussion will focus on the electro-mechano-chemical system constraints of deep brain interventions, with a particular focus on low-power circuit design challenges.



BIONic Neuromuscular Interfaces

Gerald Loeb, University of Southern California, Los Angeles, California

Control of muscles and limb movements poses special challenges for neural prosthetics because the action is in the periphery rather than the mechanically protected and physically localized central nervous system. Multiple, widely spaced devices must be implanted and controlled without encumbering the patient and they must function for decades in an extremely hostile environment. The unusual form factor of an injectable hermetic package (BION = BIOnic Neuron) dictates the use of a single ASIC that supports bidirectional RF communication, low-noise signal detection, high voltage stimulation, complex digital control and low power consumption. Development and clinical testing of such disruptive but highly regulated technology in an academic research environment has posed further challenges.

Cochlear Implant Technology – The Bionic Ear

Peter Seligman, Cochlear, East Melbourne, Australia

Cochlear implants have become an established prosthetic device to help people who have lost all their useful hearing. Cochlear implants are distinct from hearing aids, which amplify sound. The sensation of hearing is restored by electrical stimulation of the auditory nerve in inner ear. The prosthesis consists of two parts, a surgically implanted device in a hermetic capsule and an externally worn sound processor that includes a microphone and a battery. The sound processor communicates with the implant via a radio frequency inductive link. The hearing sensation is produced by analysing the sound into typically 16 to 22 frequency bands and stimulating nerves approximately corresponding to these frequencies in normal hearing.

The Cochlear Implant is designed to last for the lifetime of the recipient but upgrades to the external hardware are periodically available, with improvements in convenience and sound quality.

Challenges in Retinal Prosthesis

Wentai Liu, University of California, Santa Cruz, CA

Efforts are underway to restore functional vision in blind patients with Retinitis Pigmentosa (RP) and Age Related Macular Degeneration (AMD). Results from preliminary implants in humans for retinal prosthesis indicate great promise towards chronic high resolution systems in the future. This talk will provide the current status of the research work and describe the challenges ahead.